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Description

Method and device for switching a semi-conductor circuit breaker

The invention relates to a method for switching a semi-conductor circuit breaker according to the preamble of Claim 1, in particular a semi-conductor circuit breaker arranged between two energy storage devices in a wiring system of the vehicle equipped with an integrated starter generator. It also relates to a device for implementing said method according to Claim 4.

In a wiring system of the vehicle with ISG, switching processes are necessary between the energy storage devices - accumulators of different nominal voltages and capacitors (intermediate circuit capacitors, double layer capacitors) - via static frequency changers or switching regulators by means of circuit breakers which are carried out on the commands of a control unit.

A requirement in this case is that before a switch is opened, the switch current flowing through it is brought to 0A and that before a switch is closed, the switch voltage between its switching contacts is brought to 0V.

A switch current 0A can be carried out, for example, by disabling an AC/DC static frequency changer or a DC/DC switching regulator and causes no problem in practice.

Regulation to the 0V switch voltage, i.e. no potential difference between the poles of the (opened = non-conductive) switch, usually takes place by purposefully reversing the charge of one of the energy storage devices, for example, an intermediate circuit capacitor because this capacitor is usually the smaller energy storage device. In principle, this

regulation can also be carried out by means of a static frequency changer or a switching regulator positioned between said static frequency changer and the wiring system of the vehicle.

The intermediate circuit capacitor for example has a capacity of several 10.000μF, the double layer capacitor for example a capacity of 200F and the accumulators a capacity of several Ah. The switch voltage to be equalized can be up to a voltage of 60V.

However, determined by the unfavorable ratio of the power of the static frequency changer (e.g. 6kW) or the switching regulator (e.g. 1kW) to the energy required for charge equalizing (up to 40 joules), stringent limits have also been set in practice for voltage equalizing.

If now for example, for reasons of reliability and space requirements, semi-conductor switches are used as switches, the accuracy of voltage equalizing which can be achieved in this way is not sufficient.

Currents and power outputs occurring during normal operation require the application of components (capacitors, switches) with very low resistances. In the case of existing voltage differences, the equalizing currents are accordingly high via the switch to be closed. In extreme cases, this leads to a destruction of the semi-conductor.

A limitation of the equalizing current flowing through the switch to a safe value requires a current measurement, which necessitates a cost-intensive current sensor at the peak of the occurring currents. In addition, the equalizing process cannot be carried out time-optimized because in the case of an excessive switch voltage, the power loss in the switch is high which represents a further possible limitation.

It is the object of the invention to create a method and a corresponding device for actuating a semi-conductor circuit breaker which functions without a cost-intensive current sensor and in the case of which the transient effect and the closed circuit condition are controlled in such a way that also in the case of a high voltage difference at the switch, the power loss in semi-conductors is limited to a safe value and kept constant so that damage to the semi-conductor is excluded.

This object of the invention is achieved according to the invention by means of a method according to the features of Claim 1 and a device according to the features of Claim 4.

Advantageous further developments of the invention can be taken from the subclaims.

The invention includes the technical theory to control the resistance of the breaker gap of the semi-conductor circuit breaker (S1, S2) by a control voltage Vst to such an extent that the power loss Pist from the circuit breaker (S1, S2) does not exceed a predetermined setpoint Psoll.

The power loss Pist from the circuit breaker is determined from the differential voltage Vdiff between the connections of the circuit breaker as is explained in greater detail below.

This power loss Pist is then regulated to a predetermined setpoint Psoll, in which case the controlled variable is used as the control signal in order to generate the control voltage.

According to the invention, provision is made for embodying the switch as a transfer gate and for controlling it in such a way by means of a charge pump, that the power loss can be controlled at the switch and limited to a predetermined setpoint.

Advantageous further developments of the invention can be taken from the subclaims.

An embodiment of the invention is explained below on the basis of the accompanying drawing. The drawings show:

Figure 1 a basic circuit diagram of a 14V/42V wiring system of a vehicle,

Figure 2 a basic circuit diagram of a semi-conductor circuit breaker embodied as a transfer gate,

Figure 3 the circuit of a transfer gate, which can be controlled by means of a charge pump,

Figure 4 a differential amplifier with a rectifier to determine the voltage of the switch,

Figure 5 an analog computer to determine the power loss at the switch with a two-state controller connected downstream, and

Figure 6 a flow diagram to determine the power loss from the switch.

Figure 7 the graph of the time-variable command variable Vsoll(t), and

Figure 8 an alternative embodiment for the power loss computer LR according to Figure 5.

Referring to the device, the method according to the invention is explained in greater detail on the basis of the embodiments.

Figure 1 is a basic circuit diagram of a 14V/42V wiring system of a vehicle with an integrated starter generator ISG connected to an internal combustion engine (not shown) on the basis of which the invention is explained.
This ISG is connected by means of a bidirectional AC/DC converter AC/DC

a) directly to an intermediate circuit capacitor C1,
b) via a circuit breaker S2 to a double layer capacitor DLC,
c) via a circuit breaker S1 to a 36V accumulator B36 and a 42V wiring system of a vehicle, and
d) via a bi-directional DC/DC converter DC/DC to a 12V accumulator B12 and a 14V wiring system of a vehicle N14.

According to the invention, each circuit breaker (S1 and S2) should be embodied as a transfer gate, which is controlled by a charge pump actuated by the commands from a control unit which is not shown.

Figure 2 is a basic circuit diagram of a switch embodied as a transfer gate TG, for example, for the switch S2, which is arranged between the intermediate circuit capacitor C1 and the double layer capacitor DLC. If further switches other than the switches embodied as a transfer gate are required, they will be embodied identically.

The transfer gate TG consists of two MOSFET transistors Q1 and Q2 connected in series whose source connections s and gate connections g are interconnected in each case. The drain connections d serve as input E or output A of the switch. Because in the wiring system of a vehicle, the voltage differences Vdiff and the current directions at the switch can have any leading sign or any direction, two semi-conductors or semi-conductor groups connected in series must be used of which at least one of them is blocked in each case. Such an arrangement is known as the transfer gate, which practices the actual switching function.

The control of such a switch embodied as a transfer gate takes place by applying a control voltage between the source connection and the gate connection. In order to reduce the

control voltage, a resistor not described in greater detail in this case is provided between the gate and the source connection.

In Figure 3, the circuit of switch S2 embodied as a transfer gate which can be controlled by a charge pump, said circuit being arranged between the intermediate circuit capacitor C1 and the double layer capacitor DLC, is shown once more. In addition, it is possible that by means of a signal Dis via a further transistor Q3 arranged in the transfer gate (and an external transistor Q4), the control voltage can be short-circuited in order to open the transfer gate quickly (to be controlled in a non-conductive manner).

The known charge pump LP (capacitors C2 up to C5 and diodes D3 up to D5) sets up a control voltage between the source connection and the gate connection of the transfer gate (switch 2). It is supplied by a gate oscillator (logical circuit elements U1 up to U4) having an enable function. In this way, both the oscillator and the charge pump LP can be enabled and disabled by a logical control signal En (enable). The generation of this control signal En is explained further below.

By enabling the charge pump LP by means of a signal En (enable), a positive control voltage is set up between the source connection and the gate connection as a result of which switch S2 (transfer gate) accordingly becomes conductive. After the disabling process, this voltage is again reduced as a result of which switch S2 again becomes non-conductive. The enabling and disabling takes place controlled in time, i.e. by means of explicitly enabling and disabling the charge pump, the transfer gate can be kept in an analog conductive state. The voltage (potential difference) Vdiff between the

connections A and E of switch S2 (transfer gate) is determined by a subsequent voltage transmitter GV shown in Figure 4 and converted to an absolute value Vdiffabs of the switch voltage referred to a reference potential GND. The voltage Vdiff is recorded in a differential amplifier A1 and R11 to R14 and converted to a direct voltage referred to a predetermined reference voltage Vref. If the potential difference is 0V, then a voltage Vref can be tapped at the output of the differential amplifier A1.

A rectifier K1 connected downstream of the differential amplifier A1 evaluates the output signal of the differential amplifier A1 referred to the reference voltage Vref. It controls two interconnected switches S3 and S4 (for example, two CMOS change-over switches) so that a subsequent, second differential amplifier A2 to which resistors R15 to R18 are allocated, always keeps a positive input voltage.

In this way, the absolute value Vdiffabs of the switch voltage Vdiff referred to the reference potential GND is obtained at the output of the differential amplifier A2.

In order to determine the power loss from the switch Pist, this absolute value Vdiffabs of the switch voltage must be prepared further.

In order to avoid a costly measuring of the switch current I_S, it is also possible to determine it from the differential of the switch voltage Vdiffabs because this current serves to reverse the charge of the intermediate circuit capacitor C1:

$$I_S = C1*d(Vdiffabs)/dt, \qquad \text{thus C1 is constant} \qquad (1)$$

In order to determine the power Pist at the switch, the

product of the switch voltage V_S and the switch current I_S must be determined:

$$Pist = V_S*I_S = Vdiffabs*C1*d(Vdiffabs)/dt \qquad (2)$$

According to Figure 5, a performance calculator LR is used to calculate the power of the switch Pist. This consists of an analog computer A3 and a multiplier M connected to a capacitor C21 and a resistor R21. The analog computer A3 calculates, according to formula 2, the differential d(Vdiffabs)/dt in time from the input variable Vdiffabs which is multiplied in the multiplier M by the input variable Vdiffabs.

In this case, the value of the intermediate circuit capacitor C1 is taken into account as the amplification factor. However, it can also be taken into account by varying the setpoint Psoll of a subsequently described two-state controller K2. The output signal of the multiplier M is proportional to the power of the switch Pist.

In a subsequent two-state controller K2, the output signal Pist of the multiplier M is regulated to a setpoint Psoll which serves as the command variable which, as a voltage value corresponding to the setpoint Psoll, is applied to the non-inverting input of the two-state controller K2. The non-inverting input of the two-state controller K2 is connected directly to the reference potential GND via a resistor R22. The setpoint Psoll is supplied to the non-inverting input of the two-state controller K2 via a switch S~~3~~5. Signal En can be tapped at the output of the two-state controller K2, said signal being supplied to the gate oscillator U1 to U4 as a control signal according to Figure 3:

Pist<Psoll: En = High → the gate oscillator U1 starts oscillating and the charge pump generates an increasing gate voltage as a result of which the transfer gate has a higher

conductivity. The switch voltage (between A and E) drops and, as a result, also the measured voltage udiffabs. As a result of this, the value of Pist will carry on increasing until it exceeds the setpoint Psoll.

Pist>Psoll: En = Low → the gate oscillator U1 stops. The charge pump no longer supplies a gate voltage and this drops slowly. If Pist falls below Psoll, the controller K2 again switches to high and the cycle starts once again. The setpoint Psoll can be disabled by opening switch S3 in which case the resistor R22 then supplies the zero potential and S2 safely goes into the off-state.

The power of the switch Pist can also be calculated by means of a software program stored in a microcontroller μC whose flow diagram is shown in Figure 6. As a result of this, the analog computer A3 and the multiplier M are unnecessary. The output signal Vdiffabs of the differential amplifier A2 (Figure 4) is digitalized continuously in an A/D converter A/D and stored in an intermediate storage device ZS and subsequently differentiated per software (d/dt).

In a further step, the differential is multiplied (X) by the output signal of the A/D converter A/D and a constant C1 and is then reconverted to an analog value (D/A). This analog value is proportional to the power of the switch Pist and is supplied to the inverting input of the controller K2 (in Figure 5).

Differentiation and multiplication are costly methods both hardware-specifically and software-specifically. Both methods can be avoided.

Because the relevant system variables (capacity, differential

voltage Vdiffabs and the power of the switch Psoll) are known or can be measured, the control loop for controlling the process of reversing the charge can also be simplified.

For these reasons it is possible that - arithmetically or empirically - a time-variable nominal voltage Vsoll(t) allocated to a constant power of the switch Psoll can be determined and stored which is used as the command variable for the process of reversing the charge starting with the differential voltage Vdiffabs at the start of the process of reversing the charge up to the point in time when the process of reversing the charge has ended and Vdiffabs = 0V.

As can be seen in Figure 7, a parabolic graph over time is obtained for this curve. The control loop is now controlled by this time-variable voltage Vsoll(t) whose start value corresponds to the current value of the differential voltage Vdiffabs at the beginning (to) of the process of reversing the charge.

As can be seen in Figure 8, the generation of this time-variable nominal voltage Vsoll(t) as the command variable can take place by means of a microcontroller μC in which the course of the nominal voltage Vsoll(t) in time is stored in a table T. Therefore, the hardware-specific or software-specific differentiators and multipliers become unnecessary according to Figures 5 and 6.

In this embodiment, the absolute value of the differential voltage Vdiffabs (output voltage of the second differential amplifier A2 in Figure 4) is directly supplied to the inverting input of the two-state controller K2 and the input of the microcontroller μC.

This differential voltage Vdiffabs is then first of all converted to A/D in the microcontroller μC.

By means of the command not shown here for equalizing the charge of the two energy storage devices (here C1 and DLC) connected to the switch (here S2), starting (Figure 7) at the point in time (to) at which the start value Vsoll(to) corresponds to the differential voltage Vdiffabs at this point in time (to) and which is taken from the table T, the time-variable nominal voltage Vsoll(t) is supplied after D/A conversion to the non-inverting input of the two-state controller K2 via switch S3 and is plotted according to the curve shown in Figure 7 until it becomes zero at the point in time t1.

Therefore, the charge equalizing between the two energy storage devices is carried out with a predetermined, constant power loss from the switch, which has ended at the point in time t1.

Patent claims

1. Method for switching a semi-conductor circuit breaker (S1, S2),

characterized in that

the resistance of the breaker gap of the semi-conductor circuit breaker (S1, S2) is controlled by a control voltage Vst to such an extent that the power loss Pist from the circuit breaker (S1, S2) does not exceed a predetermined setpoint Psoll.

2. Method according to claim 1, characterized in that for determining the power loss Pist from the circuit breaker (S1, S2), from the differential voltage Vdiff between the connections (S1, S2), the absolute value Vdiffabs of this differential voltage Vdiff is formed referred to the reference potential GND,

the differential d(Vdiffabs)/dt in time of this differential voltage Vdiff is formed,

according to the formula

$Pist = V_S*I_S = Vdiffabs*d(Vdiffabs)/dt*C1$,

with V_S = switch voltage Vdiffabs,

$I_S = d(Vdiffabs)/dt*C1$,

$C1 = const$,

the differential d(Vdiffabs)/dt in time is multiplied by the absolute value Vdiffabs and a constant value C1, in which case the product of the circuit breaker (S1, S2) corresponds to the power loss Pist, and

the power loss Pist is regulated to a predetermined setpoint Psoll, in which case the controlled variable serves as the control signal En for generating the control voltage Vst.

3. Method according to claim 1, characterized in that from the differential voltage Vdiff between the connections of the circuit breaker (S1, S2), the absolute value Vdiffabs of this differential voltage Vdiff is formed referred to the

reference potential, from the known or measurable system variables such as capacity C1, differential voltage Vdiffabs and the power of the switch Psoll, a time-variable nominal voltage Vsoll(t)allocated to a constant power of the switch Psoll can be determined and stored for the process of reversing the charge, and
this nominal voltage Vsoll(t) is used as the command variable for regulating the differential voltage Vdiffabs for the process of reversing the charge starting with the differential voltage Vdiffabs at the start (to) of the process of reversing the charge up to the point in time t1 when the process of reversing the charge has ended and Vdiffabs = 0V, in which case the controlled variable serves as the control signal (En) for generating the control voltage Vst.

4. Device for implementing said method according to one of the claims 1 to 3 for actuating a circuit breaker (S1, S2), in particular a semi-conductor circuit breaker (S1, S2) arranged between two energy storage devices (C1, DLC, B36) in a wiring system of the vehicle equipped with an integrated starter generator(ISG),
c h a r a c t e r i z e d in that
the circuit breaker (S1, S2) is embodied as a transfer gate (TG) with two semi-conductors (Q1, Q2) connected in series of which, in the off-state of the circuit breaker (S1, S2), at least one of them is blocked, and
for generating the control voltage Vst, a charge pump (LP) is provided by means of which the semi-conductors (Q1, Q2) of the circuit breaker (S1, S2), in the conductive state, are in each case only controlled to such an extent that the power loss Pist from the circuit breaker (S1, S2) does not exceed a predetermined setpoint Psoll.

5. Device according to claim 4, characterized in that a transistor (Q3) is provided in the transfer gate (TG), the

collector emitter route of said transistor being arranged between the interconnected gate connections (g) and the interconnected source connections (s) of two semi-conductors (Q1, Q2) connected in series which can be shifted by means of an external signal (Dis) to the conductive state in order to control the transfer gate (TG) quickly in a non-conductive manner.

6. Device according to claim 4, characterized in that for determining the power loss Pist from the circuit breaker (S1, S2),

- a voltage transmitter (GV) is provided which from the differential voltage Vdiff between the connections (A, E) of the circuit breaker (S1, S2) forms the absolute value Vdiffabs of this differential voltage Vdiff referred to the reference potential GND,
- a differentiator (A3, d/dt) is provided in which the differential d(Vdiffabs)dt in time is formed, and
- a multiplier (M) is provided which multiplies the differential d(Vdiffabs)/dt in time by the absolute value Vdiffabs and a constant value C1 and whose output signal conforms to the power loss Pist from the circuit breaker (S1, S2).

7. Device according to claim 4, characterized in that a microcontroller (µC) is provided in which the power loss Pist is determined digitally,
with an A/D converter (A/D) which continuously digitalizes the output signal Vdiffabs of the differential amplifier (A2),
with an intermediate storage device (ZS) in which the digitalized signal Vdiffabs is stored,
with a digital differentiator (d/dt) which differentiates the stored signal Vdiffabs to d(Vdiffabs)/dt,
with a digital multiplier (x) which multiplies the digital signal Vdiffabs by the differential d(Vdiffabs)/dt and a

constant C1 to a value corresponding to a power loss Pist from the circuit breaker (S1, S2), and
with a D/A converter (D/A) which converts this digital value to an analog value Pist.

8. Device according to claim 4 or 6, characterized in that a controller (K2) is provided which regulates the power loss Pist to a predetermined setpoint Psoll, and whose output signal, the controlled variable is supplied as a control signal En to the charge pump (LP) to generate the control voltage Vst.

9. Device according to claim 8, characterized in that the controller (K2) is a two-state controller.

10. Device according to claim 4, characterized in that a voltage transmitter (GV) is provided which from the differential voltage Vdiff between the connections (A, E) of the circuit breaker (S1, S2) forms the absolute value Vdiffabs of this differential voltage Vdiff referred to the reference potential,
a microcontroller (μC) is provided to which the differential voltage Vdiffabs is supplied in which the time-variable nominal voltage Vsoll(t) is stored in a table (T), and
a controller (K2) is provided to which the differential voltage Vdiffabs is supplied to its inverting input and the time-variable nominal voltage Vsoll(t) to its non-inverting input, and whose output signal, the controlled variable is supplied as a control signal En to the charge pump (LP) to generate the control voltage Vst.

Abstract:

The invention relates to a method for switching a semi-conductor circuit breaker by means of which the resistance of the breaker gap of the semi-conductor circuit breaker is controlled by a control voltage (Vst), such that the power loss (Pist) from the circuit breaker does not exceed a predetermined setpoint (Psoll). The invention also relates to a device for carrying out said method wherein a transfer gate, which is controlled by a charge pump, is used as a semi-conductor circuit breaker.